RESIDENTIAL WOOD CHIP STOKER DEMONSTRATION

37

RUNDLE INDUSTRIES, LTD.
Fredericton, N.B.
February, 1985

C.R.E.D.A. PROJECT #2034

Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

The Conservation and Renewable Energy Demonstration Program Program is administered in New Brunswick by the Energy Secretariat and managed jointly with Energy, Mines and Resources Canada. The Program is designed to help demonstrate promising conservation and renewable energy technologies, to develop public awareness and understanding of these technologies, and to create employment in new or existing industries.

Through over 100 demonstration projects in New Brunswick, a wide variety of conservation and renewable energy technologies have proven to be technically sound and economically attractive. These demonstration projects should now provide a catalyst for commercialization and lead to widespread adoption of many of these proven technologies.

This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

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Le Programme de démonstration des économies d'énergie et des énergies renouvelables est administré au Nouveau-Brunswick par le Secrétariat à l'énergie, en collaboration avec Energie, Mines et Ressources Canada. Ce programme tente d'abord de vérifier la fiabilité des techniques de conservation d'énergie, d'accroître la sensibilité du public envers ces techniques et, enfin, de favoriser la création d'emplois au sein des industries nouvelles ou déjà existantes.

Un grand nombre de projets de démonstration se sont avérés à la fois techniquement réalisables et économiquement attrayants.

Le succès ainsi rencontré encourage la commercialisation des procédés les plus accessibles. Cela entraînerait certes l'adoption d'un grand nombre de ces techniques par les propriétaires de domiciles et par l'industrie privée.

Ce rapport final est basé sur un projet qui a reçu une aide financière du Programme de démonstration. Pour de plus amples renseignements, communiquez avec la:

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D I S C L A I M E R

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1. EXECUTIVE SUMMARY

The main objective of this demonstration project was to develop a working production model of a wood chip stoker. A stoker is an automatically-controlled device which feeds fuel to a combustion chamber when a thermostat indicates a need for heat. Five models were developed and installed, each reflecting progressive improvements discovered during the duration of the project. (See photographs in Appendix B.)

The project was successful in the sense that out of the five units constructed a final production model emerged which performed as anticipated. The performance of three of the five units was judged to be fair to excellent and the other two were assessed as being poor and good, respectively.

All subsequent production models will be manufactured in such a way as to reflect all lessons learned during the course of this project.

Project manager was Mr. Peter Rundle, President, Rundle Industries Ltd.

Funding assistance for this project was provided by Energy, Mines and Resources Canada (EMR) and the New Brunswick Energy Secretariat (N.B.E.S.) under C.R.E.D.A.

1. RESUME

Ce projet de démonstration avait pour principal but de développer un modèle de production opérationnel d'un chargeur de copeaux de bois. Ce dernier est un appareil contrôlé automatiquement pour alimenter la chambre de combustion lorsque le thermostat indique un besoin en chaleur. On a développé et installé cinq modèles, chacun reflétant les améliorations découvertes durant la durée du projet. (voir les photographies à l'annexe B.)

Le projet a été une réussite, car des cinq unités construites, le modèle de production final a présenté les performances prévues. Le rendement de trois des cinq unités a été jugé de bon à excellent et les deux autres ont respectivement été évaluées de pauvre à bon.

Tous les modèles ultérieurs seront manufacturés de telle manière à refléter les leçons apprises au cours de ce projet.

M. Peter Rundle, président de Rundle Industries Ltd, a occupé le poste de gérant du projet.

L'aide financière pour la réalisation de ce projet a été apportée par Energie, Mines et Ressources Canada (EMR) et le Secrétariat à l'énergie du Nouveau-Brunswick en vertu de l'Accord de démonstration des économies d'énergie et des énergies renouvelables (ADEEER).

2. INTRODUCTION AND BACKGROUND

Since the Arab oil crisis of 1973, more and more New Brunswickers are burning stick wood in an ongoing effort to reduce their heating bills. Unfortunately, one of the major drawbacks to burning stick wood is that it is not very convenient because the wood must be fed manually to the furnace or stove rather frequently.

If the fuel were in particulate form, such as chips or sawdust, it could be fed automatically by a thermostatically controlled motor-driven auger unit.

Realizing the potential of wood residue when transformed to wood chips, two University of New Brunswick Forestry professors, Dr. M. Schneider and C.A. Short, through funding from the New Brunswick Energy Secretariat, demonstrated how to provide the space heating needs of single-family dwellings by burning wood chips in stoker-fed furnaces. The installations were installed by Short and Schneider in 1979 and have been under test since that time with considerable success. The results of that project are contained in a publication entitled "Residential Wood Chip Furnaces" and is available from the Energy Secretariat, P.O. Box 6000, Fredericton, N.B., E3B 5H1.

The system chosen for their study was a chip-fired under-fed stoker similar to those used in Scandinavia and not very

different from the domestic coal-burning stokers which were fairly common in North America at one time.

Rundle Industries Ltd., realizing the commercial potential of such a research project, built a modified version of the Schneider prototype and submitted a proposal to the Energy Secretariat for installing five of these units in various residences within the province.

The major performance objective of the demonstration was that the unit be capable of heating a typical single-family dwelling in a safe and reliable way.

The reason for choosing to demonstrate this kind of technology was because wood residue exists in New Brunswick in adequate quantities.

3. DESCRIPTION OF THE DEMONSTRATION

The project consisted of building five wood chip stokers and installing them in three dwellings in Fredericton and two residences in Bristol, New Brunswick. All five stokers were not developed at the same time. A model was built, installed and tested. Subsequent stokers incorporated improvements discovered while building previous units. (See Appendix B). Essentially, the stoker consists of a hopper, a conveyor mechanism (augers) and a fire bowl inserted into a woodburning furnace. (See Fig. 1 below).

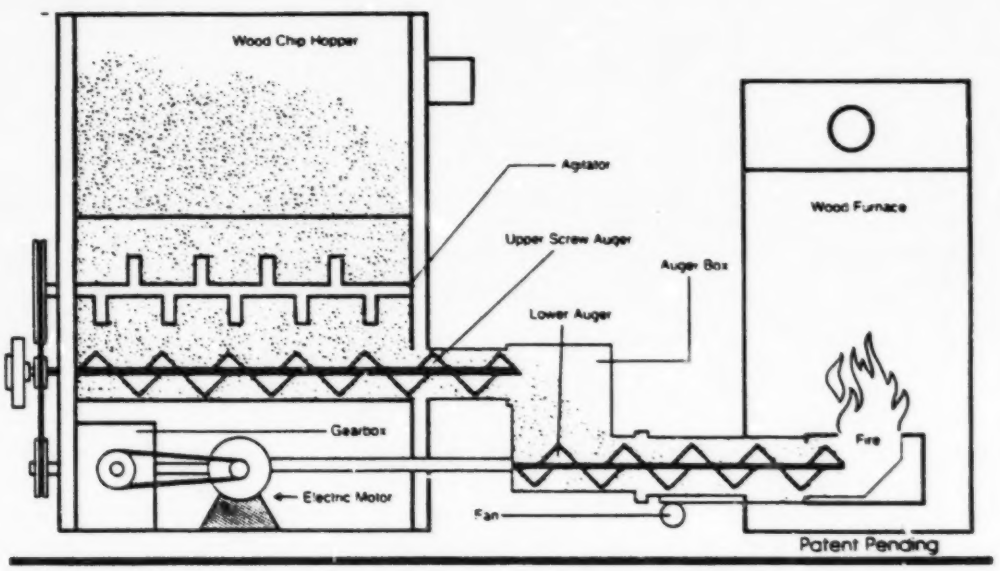


Fig. 1 - Woodcan Wood Chip Stoker

4. OBSERVATIONS DURING INSTALLATION AND MONITORING

The first unit was installed in the home of Lloyd Steeves of Fredericton, N.B. Mr. Steeves had a Kerr Scotsman wood furnace in his home which was modified for the stoker insert. Basically, this amounted to the fabrication of a lower steel chamber welded to the bottom of the furnace. This not only allowed for the insertion of the burning bowl, but also allowed for a second door through which ash can easily be removed. This modification was made on three of the units. The other two units used an Olsen-Duo Matic furnace which already was manufactured with ash removal capability. However, slight modifications to the entry side were necessary.

The unit built for Mr. Steeves' home was the first prototype and through this unit much was learned not only about the design but also about installations. (See photo 4, 5, Appendix C).

The stoker was built in one piece, not easily dismantled and too heavy. In addition, it was discovered that the width of 32" was too wide to go through most basement doorways. In the future, design changes resulted in easily dismantled units, lighter and somewhat narrower hoppers.

In all earlier stoker designs there appeared to be two potential problems. First, the system would jam and cause serious structur al damage and secondly, fire would burn back from the furnace into the wood chip hopper. In recognition of these problems, the company spent a great deal of time devising ways of eliminating these problems. Without solving both problems, the units could not have been expected to work smoothly.

The problem of jamming was due to large chips or rocks getting into the fuel. Once this occurred, the foreign substance would be jammed between the auger and the tube wall. This material would build up to the point of bending the shaft and packing like cement. Recognizing the fact that a uniform fuel was not available, the unit was designed with this potential problem in mind.

The company changed the tolerances (distance between auger and tube wall) and the shape of the auger tube from round to square. (Appendix B, Photo 2). This design allows for the larger chips to be released in the corners of the tube. After these design changes were made, the possibility of jamming has all but been eliminated. However, should a large particle be in the fuel, there are two backup systems to protect the unit, one electronic and one mechanical. (Electrical circuit overload protection and shearpin, respectively).

The burnback problem was perhaps the most serious of the two problems. The design of the unit provides for a

transition hopper or fire break between the wood chip hopper and lower auger tube. There has been occasional burnback along the lower tube especially with very dry fuel. This has almost been eliminated with proper draft control. When slight burnback did occur, it stopped well before the mechanical fire break and therefore did not present a hazard. As an added precuation against this problem, other safety devices were installed. First, a two-gallon water container was placed inside the hopper and if the temperature probe on the auger tube sensed 120 degrees Celcius, then a valve would open allowing water into the lower tube, thus extinguishing the fire. As the fire was extinguished, the valve would close retaining the remaining water for future use. In addition, a photosensor was installed in the system in order to detect if fire was present in the combustion chamber. If the fire was not present, the unit would shut off automatically.

In March of 1983 the recipients of the wood chip heating systems were asked to complete a homeowner's questionnaire. Three responses were received and the systems' performance was judged to be fair to excellent. The other two units were judged to be fair to excellent. The other two units were verbally assessed at poor to good.

The engineering consulting firm Neill and Gunter Ltd. was contracted to carry out detailed performance monitoring on the five installations included in this project as well as one other. The report of their findings is included in Appendix C.

Conclusions from this report indicated that the wood chip stokers have the potential of supplying convenient, trouble free space heating. Burning efficiencies of the units is generally high (approaching that of an oil-fired unit). Problems with auger stalling must be overcome; as well, a simple method of quality assurance for the fuel must be established. This is evidenced by the trouble free operation of the units in general when burning high quality, uniform wood chips.

5.1 COST/BENEFIT ANALYSIS

The complete project cost was $30,596, of which $23,512.15 was contributed by the N.B. Energy Secretariat and Energy, Mines and Resources Canada under the Conservation and Renewable Energy Demonstration Agreement. The remaining $7,083.85 was cost shared by Rundle Industries Ltd. ($5,583.85) and the homeowners ($1,500.00). The total amount was broken down into the following:

1)	Installation of five units	$12,096.00
2)	Engineering	3,000.00
3)	Performance Monitoring	9,500.00
4)	Information Transfer	3,500.00
5)	Project Management	2,500.00
	TOTAL	$30,596.00

5.2 PAYBACK ANALYSIS FOR REPEAT PROJECT

1984 total system cost (replacement of existing oil furnace)

i)	Stoker	$ 2,700
ii)	Installation	300
iii)	Wood-burning furnace	800
	TOTAL	$ 3,800

5.2.1 L. STEEVES

Wood Chip Cost

Consumed = 5042.2 kg. or 1,118.5 lbs = 5.56 tons

Cost = 5.56 tons X $42/ton = $233.50

Equivalent Oil

$$\frac{\text{Heat Required}}{(\text{Heating value of oil} \times \% \text{ efficiency})} = \text{litres consumed}$$

$$\frac{87,334.3\text{MJ}}{(39\ \text{MJ/l} \times 0.75)} = 2985.8 \text{ litres}$$

Cost of oil = 2985.8 l X $.359/l

= $1,072

Annual Savings = $1,072 - $233.50

= $ 838.50

Payback = $3800/$838.50 = 4.5 Year

5.2.2 P. RUNDLE

Wood Chip Cost

Consumed = 6259 kg or 13,801 lbs = 6.9 tons

Cost = (6.9 X $42/ton) = $290

Equivalent Oil

Heat req'd = 97,847 MJ

$$\frac{97,847}{(39 \times .75)} = 3,345 \text{ l}$$

Cost of oil = (3345 l X $.359/l) = $1,200

Annual Savings = $1200 - $290 = $910

Payback = $3800/$910 = 4.2 years

5.2.3 COMMUNITY INDUSTRIES

Wood Chip Cost

Consumed = 10,427.1 kg or 22,991 lbs = 11.5 tons

Cost = 11.5 tons X $42/ton = $483

Equivalent Oil

Heat Req'd = 170,417.6 MJ

$$\frac{170,417.6}{(39 \times .75)} = 5826 \text{ litres}$$

Cost of Oil = (5826 l X $.359/l) = $2,092

Annual Savings = $2,092 - $483 = $1,609

Pay Back = $3800/$1609 = 2.36 years

5.2.4 C. McNAIR

- insufficient data

5.2.5 D. ROGERS

- insufficient data

6. CONCLUSIONS

1. The greatest problem encountered during the demonstration period was the lack of suitable fuel. It was difficult to promote the wood chip heating concept because of this reason at times. The question was constantly asked "I like the idea and the way it operates but how do I obtain my fuel?" This question could never be properly answered. Therefore, once systems are installed under a project of this nature, a parallel wood chip supply should be available.

2. The general reaction to the new concept of residential wood chip heating was generally found to be quite positive especially in the rural communities. People seem to like the convenience and the degree of independance which wood residue provides over other heating alternatives in addition to the cost savings.

3. In the first stages of the demonstration period, the proponents of the project thought that the market for future wood chip units would be as retrofits to existing wood furnaces. Although this market should not be neglected, a strong demand for complete stoker-furnace units to replace expensive oil systems was observed. The project manager feels there may also be a future for the complete stoker-furnace in new homes.

4. It was found advisable to suggest to the home owner that a backup heating system be maintained in the house. This allows for the house to be left unattended for extended periods of time. However, should automatic wood chip feeding systems be installed that would convey the chips from large storage bins, the backup heating unit would not be necessary.

5. Since this entire area of wood chip heating, expecially for residences, is so new, the insurance industry has voiced interest in the safety aspects of wood chip heating. Therefore, prior to any wood chip installation, the insurance people should be contacted.

6. Creosote - due to the high burning efficiency of these units and thus the total use of the combustible gases, virtually no creosote developed in the flue.

7. Low Maintenance - ash removal is required once every two to three weeks.

8. Convenience - the units heat the homes for periods of up to 36 hours on the coldest nights and maintain an even house temperature within one degree of the thermostat setting.

7. RECOMMENDATIONS

1. Further work is necessary to develop an infrastructure of supply of wood fuel in particulate form. This will increase the market potential of combustor units of the type described in this report.

2. Considerably more public education through information dissemination on the use of these types of heating systems is needed to further build public confidence in them.

3. National standards for fabrication and installation must be pursued such that widespread marketing can proceed.

4. Standards for particulate wood fuel quality must also be established such that the forest industry can take steps to provide products that are appropriate for use in the equipment.

5. Methods of reducing fabrication costs must also be developed such that a more competitive selling price can be offered to consumers thus providing economy in converting to particulate wood fuels.

APPENDIX A

INFORMATION TRANSFER

The Woodcan units were demonstrated in three ways, first at a firewood exhibition in the fall of 1982 and 1983 in Fredericton. Secondly, at an open house in Bristol showing a residential installation, wood chipping display and new wood chip equipment. Thirdly, throughout the demonstration period many visitors and tours were conducted at the Fredericton installations. In total, an estimated 500 to 700 people saw the wood chip heating system. In addition to the preceeding, 5,000 leaflets were distributed, newspaper and radio ads were taken, several magazine and newspaper articles were written and radio interviews were held.

In early May 1983, Rundle Industries Ltd. conducted a demonstration at both of the Bristol sites. This demonstration attracted approximately 50 to 70 people and each was asked to complete a wood chip survey. In total, 16 responses were received and a summary of the results are as follows:

1. What type of wood chip installation interests you the most?

a)	Residential	13
b)	Commercial	3
c)	Other	0

2. What advantage(s) do you see in wood chip heating over other conventional systems?

a)	Convenient	11
b)	Savings	8
c)	Safety	3
d)	Maintenance	4
e)	None	2

3. What disadvantages do you see with wood chip heating?

a)	Fuel supply	6
b)	Cost	2
c)	Storage	3
d)	None	2
e)	No comment	3

4. Wood you purchase a wood chip heating system?

a)	Yes	8
b)	No	2
c)	Perhaps	2
d)	No comment	4

Note: In question #2 several of the respondents gave more than one answer.

APPENDIX B:
PHOTOGRAPHS

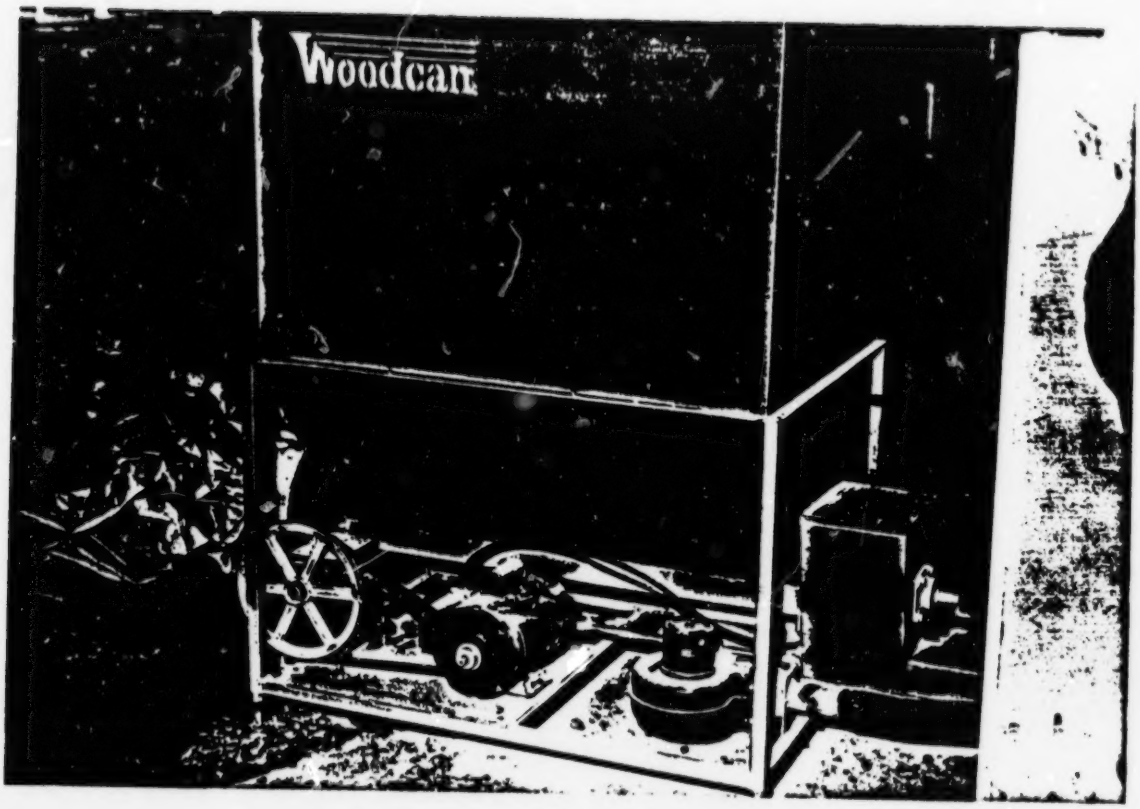


Photo 1: - Peter Rundle - 120 Alexander St.

5th Unit

Photo 2 - Hopper & Main Auger

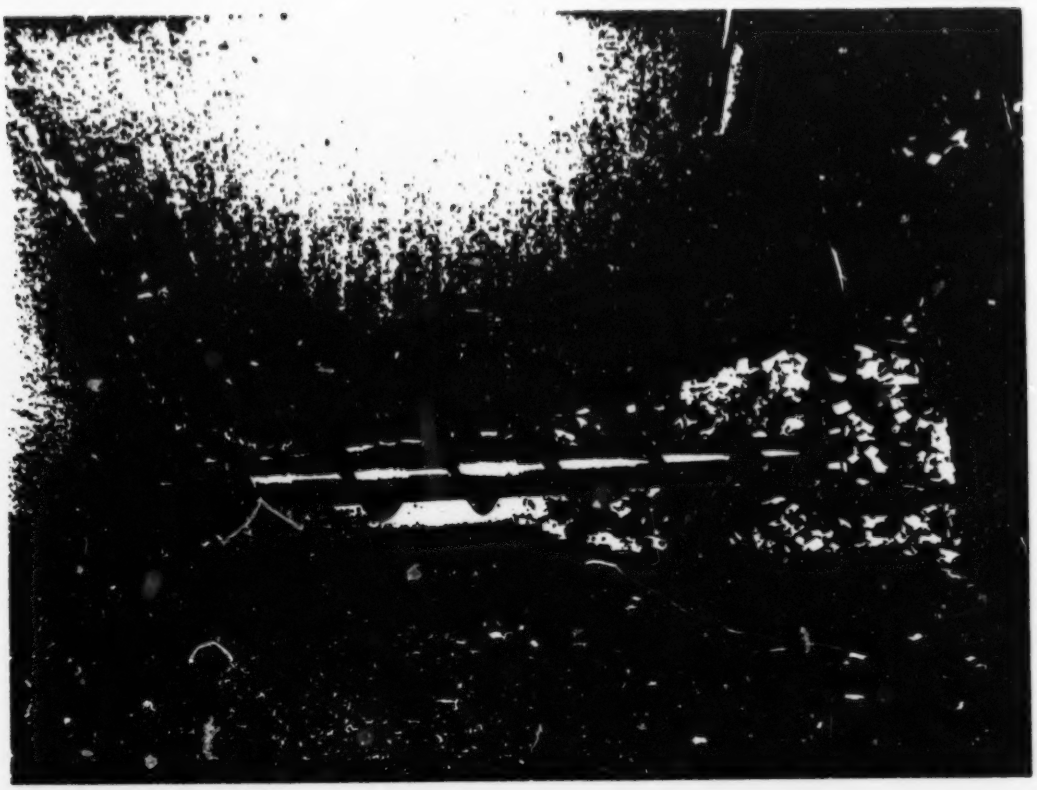


Photo 3 - 3rd prototype

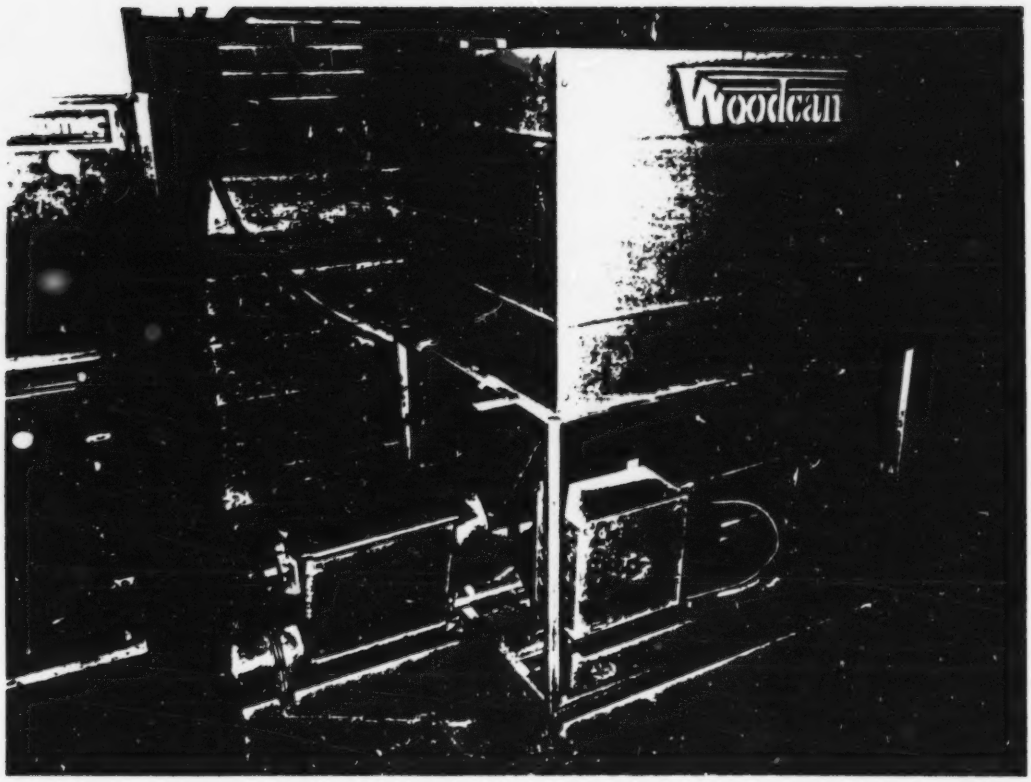
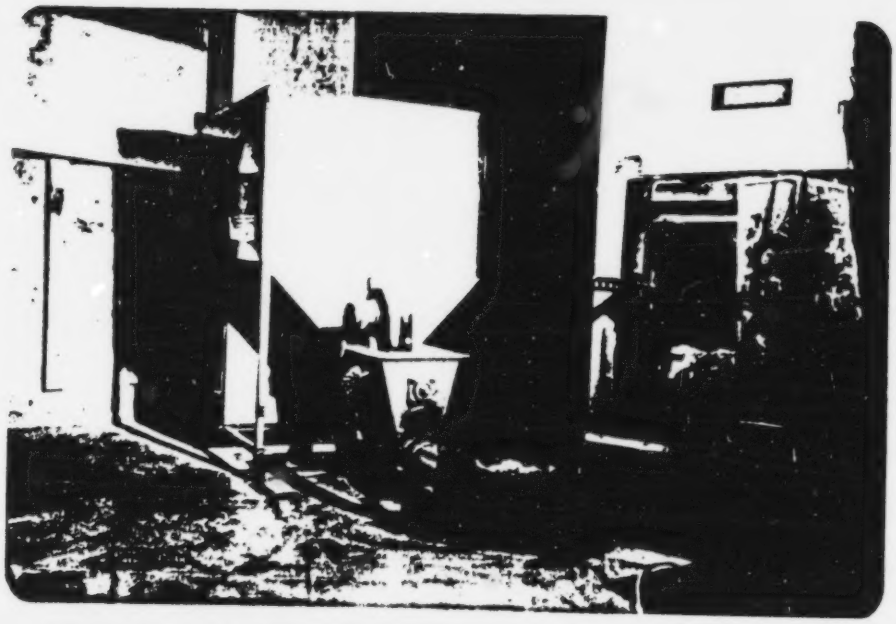


Photo 4: 1st Prototype with firebowl exposed



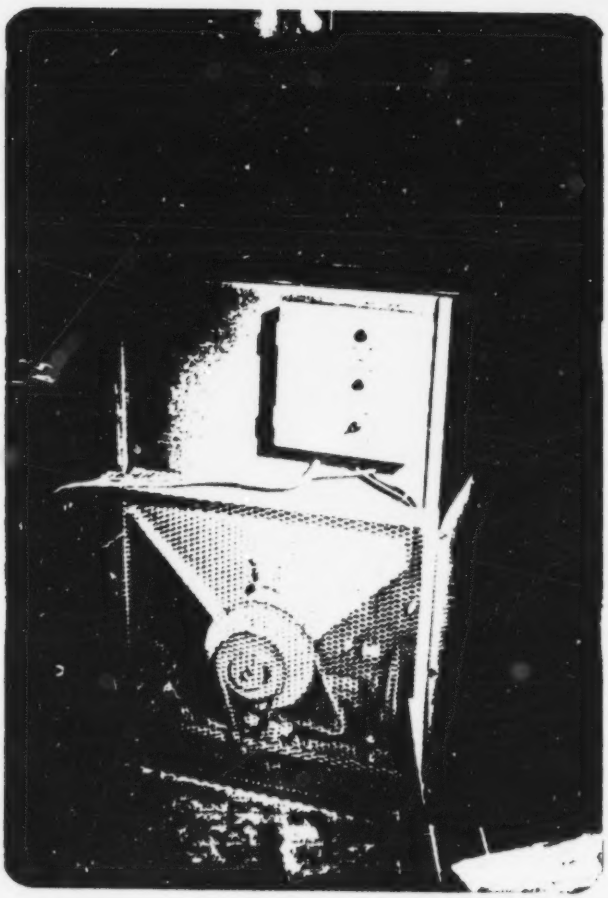


Photo 5: 1st Prototype

Lloyd Steeves

APPENDIX C: PERFORMANCE MONITORING

PERFORMANCE MONITORING OF WOOD CHIP FURNACES FOR ENERGY SECRETARIAT PROVINCE OF NEW BRUNSWICK

NGL Project No. 3185

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May 31, 1984

NEILL AND GUNTER LIMITED

Performance Monitoring of Wood Chip Furnaces

for

Energy Secretariat

Province of New Brunswick

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2. Methodology
3. Chip Tests
4. Furnace Combustion Efficiency
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7. Summary

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1. Chip Test Report by RPC
2. Furnace Efficiency Report - RPC
3. Energy Consumption Calculations

NEILL AND GUNTER LIMITED

Performance Monitoring of Wood Chip Furnaces

for

Energy Secretariat

Province of New Brunswick

1. Introduction

The Energy Secretariat of the Province of New Brunswick funded a number of demonstration projects for wood chip fired furnaces in various locations within the Province of New Brunswick. Neill and Gunter Limited of Fredericton, New Brunswick was retained by the Energy Secretariat to coordinate an energy consumption and furnace efficiency monitoring program for six of these wood chip fired furnaces. Five of the furnaces were installed by the Woodcan Division of Rundle Industries under Project No. 2034 while the sixth system was installed at Community Industries Limited of Woodstock, New Brunswick under Project No. 2014.

Neill and Gunter Limited commenced the project in July, 1983. From July to October project planning, log sheet preparation and contacts with each installation were completed. The performance monitoring commenced in mid - October, 1983 and was completed on March 15, 1984. Neill and Gunter Limited provided services for project coordination, energy consumption monitoring and preparation of this report. The Research and Productivity Council provided services for wood chip testing and furnace efficiency testing.

This report presents the results of the monitoring program. Only five installations are included in this report because one of the Woodcan installations was not tested. It was taken out of service before the field efficiency test was made.

2. Methodology

The objective of the project was to measure specific indices of performance for each furnace installation and to compare these on a common basis. These specific indices were:

(1) Energy and moisture content of the wood chips.

(2) Furnace efficiency.

(3) Energy consumption per degree day per square meter of building area.

(4) System trouble summary.

2.1 Energy and Moisture Content of the Wood Chips

A representative sample of the wood chips used at each installation was collected. In three cases these samples were collected at the time the furnace efficiency tests were conducted. In the other cases, the furnace owner collected the samples and sent them to Neill and Gunter using first class mail. In all cases the chips were placed in a heavy-walled plastic garbage bag and the bags were sealed with a locking type plastic tie.

2.2 Furnace Combustion Efficiency

The combustion efficiency of each furnace was tested using a portable fuel efficiency monitor. The tests consisted of:

flue gas temperature

furnace draft

oxygen content

smoke number

For each furnace a series of the above noted tests were taken with the furnace operating at load. Field tests were correlated with more extensive results from a similar furnace which was tested at RPC's combustion laboratory.

2.3 Energy Consumption

Each furnace owner was asked to keep a record of the monthly volume of chips consumed by the furnace. The consumption was measured by using a specific container for filling the furnace metering bin. The volume of the container was measured. The mass of chips consumed was calculated by multiplying the number of container loads used by the volume of the container and the bulk density of the chips for that specific location. The gross energy consumption for each location was calculated by multiplying the mass consumed by the "as received" energy content of the mass of chips.

The heating degree days for each month of the monitoring period was obtained from the closest meteorological station of Environment Canada. The area of building which the furance was heating and the building characteristics were obtained for each location. The gross energy consumption per heating degree day per square meter of building was calculated for each month of the monitoring period.

2.4 System Trouble Summary

A log sheet to record various operating problems and performance characteristics was prepared. Copies of the log sheet were given to each furnace owner and they were asked to submit these on a monthly basis.

3. Wood Chip Tests

The results of the chip tests for each location are summarized in Table 1 below. RPC's report is contained in Appendix 1.

Table 1

Wood Chip Tests

Location	Energy Content (As Rec'd) MJ/Kg	Bulk Density (As Rec'd) Kg/m^3	Moisture (Wet Basis) %
Steeves	17.32	225.3	11.3*
McNair 1	16.29	229.1	16.3
McNair 2	17.11	190.9	12.6*
Rundle	16.19	228.2	17.3
Rogers	16.76	233.9	14.2
Community Industries 1	16.44	250.1	14.6
Communits Industries 2	16.22	272.1	16.0*

* Moistures at time of furnace efficiency test.

With the exception of Community Industries Limited, all chips were delivered in the late summer and fall of 1983 and were stored indoors adjacent to the furnace space. Chips were generally mixed hardwood and softwood species.

4. Furnace Combustion Efficiency Tests

4.1 Furnace Data

Each of the Woodcan installations consists of a fire bowl which has been added to the combustion chamber of a standard commercial solid fuel furnace, an under feed auger to the fire bowl, combustion air fan and a fuel metering hopper with a separate outfeed screw to the under feed auger. No two furnaces are the same. The Community Industries installation consists of a Fire Fly combustion unit which is ducted into the combustion chamber of a standard furnace. The furnace data is summarized in Table 2.

Table 2

Furnace Data

Location	Type	Manufacturer	Model	Rated Capacity BTU/Hr.
Steeves	Hot Air	Kerr	Scotsman DB101	140,000
McNair	Hot Water	New Yorker		65,000
Rundle	Hot Air	Olson	Duomatic CWF	100,000
Rogers	Hot Air	New Mac	WB-1W	80-100,000
Community Industries	Hot Air	Valley Comfort	RB4	200,000

4.2 Test Results

The results of the furnace combustion efficiency tests are summarized in Table 3 below. RPC's report is contained in Appendix 2.

Table 3

Furnace Combustion Efficiency Tests

Location	Smoke #	Draft	Stack Temp.	O_2	Fuel Moisture	Combustion Efficiency
		in H_2O	°C	%	%	%
Steeves	8	0.015	241	14.1	11.3	74
McNair	9	0.030	438	12.1	12.6	61
Rundle	9	0.020	510	10.3	17.3	62
Rogers	8	0.025	375	1.6	14.2	82
Community Industries	7	0.075	484	2.6	16.0	81

Although each of the furnaces are different in capacity, types of construction, and heat transfer surface, there is a good correlation between the combustion efficiencies and the flue gas oxygen content. There is some measure of correlation between the combustion efficiencies and the fuel moisture contents and stack temperatures.

5. Energy Consumption

The building details and the gross energy consumed per square meter of ground floor area per heating degree day are summarized in Table 4 below. Detailed calculation sheets for each location are contained in Appendix 3.

Table 4

Unit Energy Consumption

Location	Type of Dwelling	Area Consumed	Energy	Period
		m^2	$KJ/m^2/^oD$	
Steeves	2-storey R-12 walls R-30 ceiling	78.0	407.7	Nov 1/83 to Feb 29/84
McNair	1-1/2 storey R-12 walls R-20 ceiling	95.1	No Report	
Rundle	2-storey R-0 walls R-30 ceiling	80.4	785.4	Nov 18/83 to Jan 20/84
Rogers	2-storey + 1-1/2 storey R-20 walls R-20 ceiling	85.8	472.1	Jan 26/84 to Feb 10/84
Community Industries	1-storey commercial R-30 walls R-20 ceiling	371.6	162.2	Dec 1/83 to Mar 15/84

Only L. Steeves has supplied complete log sheets for fuel consumption. Three of the others supplied data which was either incomplete or poorly recorded and consequently required considerable interpretation. C. McNair has not supplied any information to date.

It is difficult to draw conclusions from the energy consumption data. The construction, insulation and occupancy of each building is different and the capacity, type of construction and heat transfer surface of each furnace is different. The Community Industries furnace was generally operated during the daytime only, which accounts for their low energy consumption.

The Steeves and Rogers locations are the most similar in building type and insulation values and have a reasonably close unit energy consumption. The Steeves location is occupied by two adults and is vacant during the working day while the Rogers location is occupied by four adults and is continuously occupied.

6. Trouble Summary

Problems with the systems can be classifed into two categories:

- Operating
- Mechanical

6.1 Operating

All of the units operated reasonably well. Three of the four Woodcan units had problems with unburnt chips in the ashes. Two of these (Mcnair & Rogers) increased the size of the fire bowl and the air holes in the bowl which appears to have corrected the problem. The third installation (Steeves) has not done this and continues to have unburnt particles in the ashes.

One of the Woodcan units (Steeves) reports a continual problem with burn back in the feed auger. This unit has a circular tube for the auger casing and has the small fire bowl.

All of the Woodcan installations are sensitive to oversized chips which can stall the auger in the metering bin or the underfeed auger.

6.2 Mechanical

The major mechanical problem with the Woodcan units has been damage to the feed augers. Both Steeves and Rogers have had mechanical failures in their auger systems.

Steeves had a shaft failure, a bent auger, and a motor burn out on separate occasions. Rogers had a shaft failure and Rundle had to replace bent screw flights. It would appear that better overload protection should be provided. This could be in the form of improved or more sensitive electrical overloads, or a mechanical overload device.

7. Summary

The as received energy content of the chips used by the various locations was relatively consistent. The average energy content was 16.62 Mega Joules per kilogram. The average bulk density was 232.8 kilograms per cubic meter and the average wet basis moisture content was 14.6 percent.

The combustion efficiencies of the furnaces varied considerably. The Woodcan units ranged from a low of 61 percent to a high of 82 percent with an average of 70 percent. Each Woodcan furnace appeared to have a slightly different firebowl size and air flow which could account for the variations in combustion efficiency. The Fire Fly unit had a combustion efficiency of 81 percent.

The unit energy consumptions of the buildings showed a large variation. This is explained by the considerable difference in occupancy, building type and insulation values.

All of the furnaces operated well with low creosote levels. The only significant problem is with the feed augers on the Woodcan units which are sensitive to oversized chips and stones which can cause jamming of the auger and shaft failure.

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February 20, 1984

Mr. Gregg McKenna, P. Eng.,
Neill & Gunter
P.O. Box 713
Fredericton, N.B.
E3B 5B4

Dear Mr. McKenna:

The final results of the wood chip analyses have now been received. They are as follows:

Chip	Btu/lb. (dry basis)	Btu/lb (as rec'd)	Bulk Density (as rec'd) Kg/m³	% Moisture
Steeves	8393	7446	225.3	11.3
McNair	8366	7005	229.1	16.3
Rundle	8414	6959	228.2	17.3
C.I.	8276	7067	250.1	14.6
Rodgers	8395	7204	233.9	14.2
McNair 2	8419	7357	190.9	12.6

Steeves ash: < 250 Btu/lb.

Sincerely,

K. Todd Fraser

K. Todd Fraser
Project Leader - CDTF

P.O. Box 6000, Fredericton, New Brunswick, Canada E3B 5H1 • Telephone 506 455-8994 • Telex 014-46115 • Cable Reprodco—Fredericton

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March 1, 1984

Mr. Gregg McKenna, P.Eng.,
Neill and Gunter Ltd.,
P.O. Box 713
Fredericton, N.B.
E3B 5B4

Dear Mr. McKenna:

In response to your letter of February 17, 1984:

1. The moisture content was stated on a wet basis.

2. The sample submission dates are:

Steeves	November 9, 1983
McNair	November 23, 1983
Rundle	November 28, 1983
C.I.	December 1, 1983
Rodgers	January 19, 1984
McNair 2	January 19, 1984

3. We received only one Rodgers sample as indicated in my letter of February 20, 1984.

Please excuse the delay in making these results available.

Sincerely,

K. Todd Fraser

K. Todd Fraser
Project Leader
C.D.T.F.

KTF/sg

P.O. Box 6000, Fredericton, New Brunswick, Canada E3B 5H1 • Telephone 506 455-8994 • Telex 014-46115 • Cable Reprodco—Fredericton

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May 18, 1984

Mr. Gregg McKenna, P. Eng.
Neill and Gunter Ltd.,
P.O. Box 713
Fredericton, N.B.
E3B 5B4

Dear Mr. McKenna:

The data on a Community Industries chip sample (sample number 2) taken March 7, 1984 is now available.

Btu/lb (As rec'd)	Btu/lb (Dry basis)	Bulk Density Kg/m³ (As rec'd)	% Moisture (As rec'd)
6972	8300	272.1	16.0

As this is very similar to the previous information no change in the efficiency figures should be expected.

Finally, as this concludes our investigation, please find enclosed an invoice for the laboratory analysis of the chip samples submitted by yourselves during this project.

Sincerely,

K. Todd Fraser
Project Leader - CDTF

enclosure
sg

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EFFICIENCY TESTING OF FIVE WOOD CHIP BURNING APPLIANCES

To: Mr. G. McKenna, P.Eng.
Neill and Gunter Ltd.
P.O. Box 713
Fredericton, N.B.
E3B 5B4

By: K. Todd Fraser
Project Leader
Combustion Demonstration
and Test Facility

Report No. E/84/49
Job No. 95576
Date 1984 04 24
KTF/cjk/ES2

1.0 BACKGROUND

At the request of the New Brunswick Energy Secretariat, Neill and Gunter Limited was retained to develop and carry out a performance monitoring plan on a number of residential type wood chip fired furnaces in the province. One component of this monitoring was to be the efficiency testing of these appliances and to this end RPC was approached on Oct. 17, 1983 by Neill & Gunter.

It was agreed that the combustion testing would be carried out within the framework of RPC's Combustion Demonstration and Test Facility on a no-cost basis. The field test would consist of the measurement of smoke number, draft, $\%O_2$ or CO_2, stack temperature and efficiency. Additionally N & G would submit fuel samples for determination of moisture content, calorific value and bulk density. The standard laboratory charge would be made for this aspect of the work.

Five units were examined between Oct. 17/83 and Mar. 2/84. Seven samples were received for laboratory analysis.

2.0 TEST METHOD

Steady-state efficiencies were determined using a digitally indicating Fuel Efficiency Monitor (FEM) which measures ambient/stack temperatures (°C), and $\%O_2$ and from this computes efficiency.

Unfortunately, this device is not calibrated for wood combustion, therefore the displayed efficiency will be inaccurate. In order to overcome this problem, the field test results were compared with extensive laboratory data already accumulated on the chip burner in question. In this way the initial figures were adjusted to their proper levels.

Smoke and draft tests were performed with components from a Bacharach Combustion Test Kit.

3.0 TEST RESULTS

Units 1-4 were Woodcan chip stokers manufactured by Rundle Industries Ltd. in Fredericton. The first two were located in Fredericton and the latter two in Bristol. The fifth appliance, a Saturn Fire-Fly wood gasifier, was installed in the Community Industries building in Woodstock.

Table 1 gives results of the laboratory analysis of the wood chip samples, while Table 2 lists average readings taken and average efficiencies obtained in the field.

4.0 CONCLUSIONS

It is evident that a rather wide range of efficiencies was obtained from this testing, although this situation is readily explained.

The two best figures, Rogers 82% and Community Industries 81%, are a direct result of the low O_2 readings encountered in both these cases. The 14.6% CO_2 measured at the C.I. furnace equates to approximately 2.6% O_2.

The two poorest results on the other hand, Rundle 62% and McNair 61%, can be accounted for by the relatively high oxygen values encountered. In addition the stack temperatures and the moisture contents of the fuels used were also correspondingly high.

TABLE 1

Chip Analysis

Sample	Btu/lb (As rec'd)	Btu/lb (Dry basis)	Bulk Density Kg/m^3 (As rec'd)	% Moisture (As rec'd)
Steeves Chip	7446	8393	225.3	11.3
Steeves Ash	< 250	--	--	--
McNair Chip	7005	8366	229.1	16.3
Rundle Chip	6959	8414	228.2	17.3
C.I. Chip	7067	8276	250.1	14.6
Rogers Chip	7204	8395	233.9	14.2
McNair 2 Chip	7357	8419	190.9	12.6

TABLE 2

SUMMARY OF WOOD CHIP BURNING FURNACE
TEST RESULTS

	Steeves (Nov 9/83)	Rundle (Dec 14/83)	Rogers (Jan 18/84)	McNair (Jan 18/84)	Comm.Ind.(1) (Mar 2/84)
Draft (in. of water)	0.015	0.020	0.025	0.030	0.075
Smoke # (Bacharach/Shell Oil)	8	9	8	9	7
Ambient Temperature °C	24	23	21	20	26
Stack Temperature (ΔT + Ambient/°C)	241	510	375	438	484
Average: % O_2	14.1	10.3	1.6	12.1	2.6 (Note 1)
ΔT°C	217	487	354	418	458
% Efficiency (2)	69.1	58.1	78.1	57.0	77.0
Lo/Hi: % of O_2	15.3/12.8	11.6/7.5	2.0/1.1	13.4/10.5	--
ΔT°C	210/214	485/452	358/355	403/411	--
% Efficiency	65.6/73.1	53.9/66.9	77.7/78.5	53.3/63.0	--

Notes: 1) The Community Industries test was performed using the Bacharach Kit as the FEM was down for repairs. This means that stack temperature was measured in °F, and $\%CO_2$ (14.6) was measured, which is equivalent to about $2.6\%O_2$. As efficiencies are somewhat rougher with this method, there was no point in giving Lo/Hi values.

2) The indicated efficiencies are not correct as they stand as the FEM (Fuel Efficiency Monitor) is not calibrated for wood combustion. Comparison with laboratory data indicates that they should be approximately 4% higher, i.e.

	Steeves	Rundle	Rogers	McNair	Comm.Ind.
Actual Average Efficiency %	74	62	82	61	81
Lo/Hi Efficiencies %	70/77	58/71	82/83	57/67	--

Date: 84-05-31
File: 3185/2

Gross Energy Consumption

Location: L. Steeves
New Maryland, N.B.

1 Month	2 No. of Fillings	3 Volume Per Filling m^3/fill	4 (2x3) Volume Consumed m^3	5 Bulk Density Kg/m^3	6 (4x5) Mass Consumed Kg	7 Energy Content MJ/Kg	8 (6x7) Energy Consumed MJ	9 Building Area m^2	10 Degree - Days ^oD	11 Unit Energy $KJ/m^2/^oD$
Oct. 83	0	0.0538	0	225.3	0	17.32	0	78.03		
Nov. 83	76	0.0538	4.09	225.3	921.2	17.32	15,955.3	78.03	472.0	433.2
Dec. 83	116	0.0538	6.24	225.3	1406.0	17.32	24,352.8	78.03	759.8	410.8
Jan. 84	136	0.0538	7.32	225.3	1,648.5	17.32	28,551.6	78.03	894.8	408.9
Feb. 84	88	0.0538	4.73	225.3	1,066.7	17.32	18,474.6	78.03	618.7	382.7
Mar. 84	0	0.0538	0	225.3	0	17.32	0	78.03		
Total	416		22.38		5042.4		87,334.3		2,745.3	
									Average:	407.7

Date: 84-04-31
File: 3185/2

Gross Energy Consumption

Location: C. McNair
Bristol, New Brunswick

1 Month	2 No. of Fillings	3 Volume Per Filling m^3/fill	4 (2x3) Volume Consumed m^3	5 Bulk Density Kg/m^3	6 (4x5)7 Mass Consumed Kg	7 (6x7) Energy Content MJ/Kg	8 Energy Consumed MJ	9 Building Area m^2	10 Degree - Days ^oD	11 Unit Energy $KJ/m^2/^oD$
Oct. 83				229.1		16.29		95.1		
Nov. 83				229.1		16.29		95.1		
Dec. 83	NO REPORT			229.1		16.29		95.1		
Jan. 84				190.9		17.11		95.1		
Feb. 84				190.9		17.11		95.1		
Mar. 84				190.9		17.11		95.1		
										Average:

Date: 84-05-31
File: 3185/2

Gross Energy Consumption

Location: P. Rundle
Fredericton, N.B.

1 Month	2 No. of Fillings	3 Volume Per Filling m^3/fill	4 (2x3) Volume Consumed m^3	5 Bulk Density Kg/m^3	6 (4x5) Mass Consumed Kg	7 Energy Content MJ/Kg	8 (6x7) Energy Consumed MJ	9 10 Building Area m^2	11 Degree - Days ^oD	Unit Energy $KJ/m^2/^oD$
Oct. 83	0			228.2		16.19		80.4		
Nov. 18/83 (from)	X	N/A		228.2		16.19		80.4	223.1	
Dec. 83	X	N/A		228.2		16.19		80.4	759.8	
Jan. 20/84 (to)	X	N/A		228.2		16.19		80.4	566.7	
Feb. 84	0			228.2		16.19		80.4		
Mar. 84	0			228.2		16.19		80.4		
							97,847(a)		1,549.6	

Average: 785.4

(a) Average of:

1. 5 cords x 5.66 $\frac{m^3}{cord}$ (loose chips) x 228.2 $\frac{Kg}{m^3}$ x 16.19 $\frac{MJ}{Kg}$ = 104,556 MJ

2. 5 cords x 0.85 $\frac{cords}{cunit}$ x 1,426 $\frac{Kg}{cunit}$ (@ 17.3% MC) x 16.19 $\frac{MJ}{Kg}$ = 98,119 MJ

3. 5 cords (mixed spruce & fir) x 18,173 $\frac{MJ}{cord}$ = 90,865 MJ

Date: 84-05-31
File: 3185/2

Gross Energy Consumption

Location: D. Rogers
Bristol, New Brunswick

1 Month	2 No. of Fillings	3 Volume Per Filling m^3/fill	4 (2x3) Volume Consumed m^3	5 Bulk Density Kg/m^3	6 (4x5) Mass Consumed Kg	7 Energy Content MJ/Kg	8 (6x7) Energy Consumed MJ	9 Building Area m^2	10 Degree - Days ^oD	11 Unit Energy $KJ/m^2/^oD$
Oct. 83				233.9		16.76		85.8		
Nov. 83				233.9		16.76		85.8		
Dec. 83				233.9		16.76		85.8		
Jan. 26/84 (from)	X	X	1.74	233.9	407.0	16.76	6,821.1	85.8	185.7	428.1
Feb. 10/84 (to)	X	X	3.17	233.9	741.5	16.76	12,426.9	85.8	289.5	500.3
Mar. 84				233.9		16.76		85.8		
			4.91		1,148.5		19,248.0		475.2	
									Average:	472.1

Date: 84-05-31
File: 3185/2

Gross Energy Consumption

Location: Community Industries
Woodstock, New Brunswick

1 Month	2 No. of Fillings	3 Volume Per Filling m^3/fill	4 (2x3) Volume Consumed m^3	5 Bulk Density Kg/m^3	6 (4x5) Mass Consumed Kg	7 Energy Content MJ/Kg	8 (6x7) Energy Consumed MJ	9 Building Area m^2	10 Degree - Days ^oD	11 Unit Energy KJ/m^2/^oD
Oct. 83	0			250.1		16.44		371.6		
Nov. 83				250.1		16.44		371.6		
Dec. 83	X	N/A	10.19	250.1	2548.5	16.44	41,897.6	371.6	787.4	143.2
Jan. 84	X	N/A	11.33	272.1	3082.9	16.22	50,004.5	371.6	954.8	140.9
Feb. 84	X	N/A	12.13	272.1	3300.6	16.22	53,535.3	371.6	640.9	224.9
Mar. 15/84	X	N/A	5.66	272.1	1540.1	16.22	24,980.2	371.6	444.0	151.4
			39.31		10,472.1		170,417.6		2,827.1	
									Average:	162.2

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